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ABSTRACT

This paper reviews the empirical research that has been done with computer assisted instruction (CAI) in an attempt to gain an overview that will allow the effectiveness of CAI to be evaluated. In the review, the area of CAI is divided into four basic modes: drill and practice, problem solving, tutorial, and simulation. Each mode is defined, and relevant research is discussed. A further section discusses research in applications involving a combination of the four basic modes. Briefly, the conclusions of the review were that CAI can be an effective instructional tool, that students generally learn more rapidly but retain less with CAI than with traditional methods, that CAI is more effective for low ability students than for middle and high ability students, and that both students and teachers are highly enthusiastic towards CAI as a means of instruction. (WDR)

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THE EFFECTIVENESS OF CAI

A Paper Presented at the Annual Convention of the
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THE EFFECTIVENESS OF CAI*

Computer assisted instruction (CAI) is no longer a novelty on the educational scene. It has been found to be a technologically feasible tool in the teaching/learning process, with much time, effort, and money invested in both development and applied use. Many schools have committed extensive funds to the purchase or rental of computer equipment and materials to support CAI, while teachers have adapted their classroom instruction to incorporate available CAI resources.

Acceptance of CAI, however, is still a controversial issue for many educators. Some are wary of the uncritical adoption of yet another form of educational technology. Many are concerned about justifying the considerable financial investment involved--an especially crucial factor in combination with the call for accountability and the decline in federal funding for education.

Amid the interweaving debate of such issues a recurring question appears--a question which may indeed be the central issue: What effect does CAI have on students?

Many subjectively-based answers are often given in response to this question. Finding conclusive answers in reported research is more difficult. However,

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* In searching for research on the effectiveness of CAI it is possible that some important research may have been missed. If you know of such research that has not been included in this paper please inform the authors by writing them at Lindquist Center for Measurement, The University of Iowa, Iowa City, Iowa 52242.

there are some clues to such "hard data" to be found by examining the research literature, despite the fact that the state of the art of CAI research is still in a developing stage.

This paper focuses on research studies which report empirical data dealing with achievement of students who received instruction via one of the basic modes of application of CAI.

Since the term "CAI" itself is open to a wide variety of interpretations, it might be well to define more carefully just what is meant by computer assisted instruction as used here. CAI is seen as the use of the computer for direct instruction of students. This is in contrast to computer managed instruction (CMI), computerized testing, or teaching computer science.

This review includes research on four basic modes of CAI instruction: drill and practice, problem solving, tutorial, and simulation. These modes are briefly defined below, followed by a discussion of research related to each mode. A further section discusses CAI research in applications involving a combination of these instructional modes.

Tutorial

The tutorial mode of computer assisted instruction is intended to approximate the interaction which would occur between a skilled, patient tutor and an individual pupil. A tutorial system is used to initially present a concept and to develop a student's skill in using the concept.

The basic model is the presentation of instructional frames which elicit frequent responses from the student. Each response is then evaluated and appropriate new instructional material is presented on the basis of the pupil's responses. Much CAI tutorial material is similar to printed programmed instruction material.

A number of research studies have shown that CAI tutorial programs are at least as effective as traditional instructional modes in teaching several subject areas.

An early study reported by Atkinson (1968) concerned the first year of operation of the Stanford CAI Project as conducted at the Brentwood School in East Palo Alto, California. Visual display terminals were used in the teaching of initial reading skills to first graders. A control group received traditional classroom instruction in reading, but were exposed to CAI for mathematics instruction. In terms of achievement the group receiving CAI reading instruction preformed significantly better on the California Achievement Test and on a test developed by the Project.

In addition to better overall achievement for the CAI group, it was found that boys and girls progressed through the CAI materials at a comparable rate. This is contrary to the long accepted assumption that girls acquire initial reading skills at a faster rate than boys. A comparison of cumulative rates of progress for fastest, medium, and slowest students showed consistency over time, also suggesting the capability of CAI to accommodate individual differences.

Atkinson also reported that first graders were able to adapt well to CAI

sessions of 30-minute periods, a longer attention span than is normally attributed to this group.

similar results were reported by Fletcher and Atkinson (1972) in a later evaluation of the Stanford CAI reading program. Teletypewriter terminals with audio headsets were used for daily eight-to-ten minute sessions of computer assisted instruction in initial reading. For comparative purposes, the study used 50 matched pairs of first graders, selected on the basis of performance on the Metropolitan Readiness Test and drawn from classrooms having teachers of comparable ability.

One student in each pair was taught via the CAI program, while the other student received no CAI instruction in reading. Achievement results of the CAI group were compared with those for the group taught in traditional fashion. After one year of instruction, the CAI students made significantly greater gains in average reading grade placement as measured by posttest performance. On the Stanford Achievement Test, the average reading grade placement for the CAI group was 2.3 as compared to 1.9 for the control group. A similar difference was found on the California Cooperative Primary Test where the gain for the CAI group was 2.6 in contrast to 2.0 for the non-CAI group. These results are summarized as follows:

	Average Reading Grade Placement	
	CAI Group	Non-CAI Group
Stanford Achievement Test	2.2 boys	1.8 boys
	2.4 girls	2.0 girls
	2.3 Total	1.9 Total
California Cooperative Primary Test	2.5 boys	1.8 boys
	2.6 girls	2.2 girls
	2.6 Total	2.0 Total

Again, CAI was found to positively affect the reading progress of boys compared to girls. On the Stanford Achievement Test, the percentage of improvement due to CAI was 22% for boys and 20% for girls. Relative improvement on the California Cooperative Primary Test due to CAI was 42% for boys and 17% for girls. Cross-sex comparisons in this study seem to cooroborate the earlier finding reported by Atkinson (1968) that boys in CAI reading perform about as well as girls, suggesting a greater rate of progress for boys due to CAI.

Morgan and Richardson (1972), in describing the Montgomery County Public Schools (Maryland) Project REFLECT, reported significantly higher gain scores on standardized tests for students using tutorial CAI. The pupils were in a remediation program for Algebra II. All students were taught by the same teachers but those who had access to CAI programs made the higher scores. The total instructional time for both groups was equal.

In comparing CAI tutorial and the conventional lecture mode of instruction in teaching the basic elements of tests and measurements to prospective teachers,

Lorber (1970) found the mean posttest score of the CAI group to be significantly higher. The study, conducted at Ohio University, involved students enrolled in a test and measurement course. The experimental group received course instruction via CAI while the control group attended regular lectures. The Measurement Competency Test was administered to both groups at the conclusion of the course. In addition to achieving a higher mean score on the test, it was found that the experimental group had spent less time in instruction than had the control group. The CAI group also indicated a desire to have further contact with CAI both as users and as authors.

Cropley and Gross (1970) found no differences in achievement of students who learned the FORTRAN computer programming language through tutorial CAI, traditional, and programmed instructional methods.

Even when tutorial CAI does not result in more effective learning, efficiency is often achieved in terms of instructional time.

Proctor (1968), in comparing CAI with a lecture-discussion strategy for the presentation of general curriculum concepts at Florida State, found that the only difference between the groups was in the amount of instructional time required, which was less for the CAI group. There was no difference between the groups on achievement or retention.

In a study designed to assess the effect of CAI on attitudes toward CAI and mathematics, Kockler (1973) found similar results. At the end of the study, the 64 college level students displayed no differences in attitude but the CAI group

spent less time in instruction.

The compression of time seems also to hold true for adults as demonstrated by Krupp (1972). The Honeywell plant in Walthem, Mass. needed to teach employees general concepts of higher level computer languages and deve'op their skills in programming in HPL. Since the objectives were criterion referenced no difference was expected between the achievement levels of the CAI and lecture groups; the CAI group, however, spent an average of seven hours learning, with a range of 5-10 hours, while the lecture group spent 24-30 hours covering the same material.

Sango (1969) found that tutorial CAI significantly reduced (20%) the time required to teach basic electronics to Army draftees with no differnece in achievement levels.

Fletcher and Suppes (1972), in a study of Computer Curriculum Corporation reading program for grades four through six, found that the CAI program presented about twice as many new words as were presented in the comparable classroom text program. The increased amount of material presented was found to prevail even though students used the teletypewriter terminals for brief sessions of ten minutes.

Problem-Solving

In the problem-solving mode the student develops his own computer program for solution of a problem or a class of progrems. In analyzing it for computer solution, the student, it is claimed, gains a deeper understanding of the problem

and the algorithm for its solution. Tedious and repetitious calculations are taken over by the computer, freeing the student to focus on structure and relationships, and to search for patterns.

The most common subject area for use of the computer for problem solving has been mathematics, and the research that has been done in this mode has been in the field of mathematics, from grade 7 through college.

In the Computer Assisted Mathematics Project at the University High School, University of Minnesota, the BASIC programming language was taught to students in grades seven, nine, and eleven. All students except low achievers learned the language with no difficulty. In this program, however, Johnson (1966) found no significant differneces in achievement between students who had continued their regular mathematics curriculum and those who had, in addition, written programs in BASIC. The results were similar for grades seven, nine, and eleven.

Katz (1971) found support for these results, with a surprising twist. In six Algebra Two classes (the control group) students continued with traditional instruction. In six other Algebra Two classes, students wrote 19 computer programs relating to topics they were studying. In half of these experimental classes, the students turned their programs over to aides, who loaded and ran all of the programs on the computer. The remaining half of the students loaded and ran their own programs, always during their regular Algebra Two class period. No additional time was allowed for use of the computer. Neither of the experimental treatments (writing programs with or without running them) had a positive effect

achievement in Algebra. In fact, those who ran their own programs showed a significant decline in achievement as compared with the traditional group. Those who wrote but did not run programs achieved as well as the traditional group. It was speculated that the time taken away from class to run the programs - from 5 to 20 minutes per program - had a detrimental effect on the learning of concepts in Algebra.

The opposite effect was found in a study by Bitter (1970). Five Colorado colleges and universities participated with interested instructors teaching a "computer extended" introductory college calculus class. Students in the computer extended classes learned BASIC on their own (with a programmed text) and solved homework assignments by writing and running computer programs. Each instructor also taught a control class which covered the same content but without the computer. The students who were provided with computer extended instruction achieved significantly higher than did those in the traditional classes.

Interestingly, all of these studies report a high degree of interest and motivation on the part of students participating in use of the computer, and little difficulty in learning to program in BASIC, even for seventh graders.

Simulation

In this mode of computer use, students interact with a computer based model of reality. The model may represent an economic system, a social system, a set of physical relationships, etc. In using the simulation students learn the structure of the system, the relationships and assumptions operating, and they

have an opportunity to test and refine decision strategies. Often, a science experiment can be simulated on the computer when it is too costly, difficult, dangerous, or time consuming to perform in the school laboratory.

Computer based simulations have been developed in virtually all of the sciences, including social science. It is in those areas that research has been reported on the effectiveness of simulations in instruction.

Wing, et al (1967) reported an experiment using a computer based economics games with sixth graders in Yorktown Heights, N.Y. In interacting with the computer, students played a variety of roles, such as king, to learn how an agricultural economy works; economic adviser to understand the economic problems of an emerging nation; manufacturer to learn how capitalism works, and toy store owner to learn the economics of a retail store. On one simulation, students in the experimental (computer based) group showed a significantly higher gain from pretest to posttest than did students who learned the same economics concepts without the computer. On the other simulation, the non-computer group actually showed better long-term retention of the concepts when retested at a later time than did the computer group. However, the students using the computer simulations spent only half as much time learning the concepts. In summary, the use of the game was at least as effective as the usual classroom method, and took only half the time. Retention was poorer. The games were not as effective in teaching facts, but were superior in teaching interpretation of graphs and diagrams. Again, the students using the computer reported it to

be an enjoyable and worthwhile learning experience.

Culp and Castleberry (1971) report on two studies at the University of Texas in undergraduate organic chemistry classes. In one, an experimental group was given access to computer simulations in addition to the regular lectures and laboratory exercises. The semester test average for those students who used the computer was significantly higher than those who did not use it. In the second study, one group used supplementary computer simulations, one had supplementary tutoring from teaching assistants, and a third group had only the usual lectures and laboratory. The results were equivocal - the computer group scored significantly higher than either of the other two groups on only a few of the chemistry subtests.

Another experiment with chemistry laboratory simulation was reported by Hollen, et al (1971). Students interacted with a computer simulation to perform qualitative analysis of unknown substances, for example a substance in the Silver group. A student could, for instance, direct the computer to add 5 drops of a reagent, heat the substance, filter it, perform a flame test, and so on. The computer reported the result of each action. Some students were shown colored slides of the results, e.g. a test tube with a clear solution and a white precipitate in the bottom. Finally, the student could make a conclusion about the substance, e.g. "lead is present," and was told if he was right or wrong. The results of this study demonstrate that a simulated exercise of this type will produce terminal behaviors equivalent to (or slightly better than) traditional exercise, and at a

significant saving in student time. In view of the problems in scheduling equipment and laboratories in overcrowded courses, these findings could offer some viable alternatives.

Lunetta and Blick (1973) conducted an experiment with computer-based simulations of inductive experiments in force and motion with high school physics students. A control group performed the experiments in a traditional laboratory, using PSSC materials. One experimental group used only computer generated data sheets plus fulm loops, and a second experimental group used only film loops plus computer simulations. Analysis of the data showed that learning was significantly greater for students using the computer simulations than for either of the other two groups. Furthermore, students in the control group spent 8.3 times as long in instructional unit activities. However, retention was greater for the control group than the simulation group. A favorable attitude toward CAI was reported by both experimental groups.

Drill and Practice

The drill and practice mode of CAI involves the use of the computer to drill students in facts or to assist the student in practicing skills. With drill and practice, facts or skills are previously learned through some other mode or means. The students then use CAI drill and practice programs to memorize those facts or to practice those skills.

This has been a very popular mode of CAI and one in which considerable

research has been done, particularly in elementary arithmetic and language arts.

Arithmetic

Extensive research on the effectiveness of CAI drill and practice is arithmetic was reported by Suppes and Morningstar (1972). The students in experimental groups received from 5 to 6 minutes a day of CAI drill and practice in addition to normal classroom instruction in arithmetic. The students in the control group received only normal classroom instructior in arithmetic. The arithmetic portion of the Stanford Achievement Test was used both as a pretest and as a posttest.

About 800 California students in grades 3-6 were included in the experimental (CAI) groups in 1966-67. During that year the students in the experimental groups gained more than the students in the control (traditional) groups at all grade levels. The differences between gains of the experimental and control groups were statistically significant for all grades except the fifth. The largest difference in gains was in grade four. The experimental fourth graders scored an average grade equivalent score of 3.7 on the pretest and an average of 5.4 on the posttest, a gain of 1.7. The control group students gained an average of 1.0, from 3.8 to 4.8.

In 1967-68 the experiment was expanded to include about 1,000 California students and 600 Mississippi students in the experimental groups. First and second graders were also included during that year. This resulted in 41 comparisons of gains. Of those 41 comparisons, 29 favored the experimental groups

while 12 favored the control groups. In computation, of 18 comparisons made, 16 favored the experimental groups. In concepts, of 14 comparisons made, 7 favored the experimental groups. In applications 6 of the 9 comparisons made favored the experimental groups.

Some astonishing gains were made by the experimental groups. For example, the third grade California and Mississippi CAI groups gained, respectively, 2.28 and 2.03 grade levels in computation during the year. Over three fourths of the CAI groups 31 of 41) gained more than one grade level during the year. Half of the groups (21 of 41) gained 1.2 grade levels or more.

In general, the low ability students gained relatively more from CAI than did the middle and high ability students.

Martin (1973) reported on a study of the effectiveness of CAI drill and practice conducted by TIES, using the Suppes arithmetic programs. Their sample included 1,448 third and fourth grade students in the Minneapolis area. The sample was divided into two groups, a control group that received traditional arithmetic instruction and an experimental group that received in addition to traditional instruction, from five to seven minutes of CAI drill and practice either every day or every other day. The study took place over an entire school year with achievement measured by a pretest at the beginning of the year and a posttest at the end. The results were analyzed by type of instruction, sex, grade level, and ability level. The students who received CAI drill and practice gained more than the students who received traditional instruction only. CAI drill and

practice was most effective for boys, fourth graders, and low ability students.

In a study by Street (1972), 1,600 Kentucky students in grades three through seven received five or six minutes of CAI drill and practice per day for a period of from five to nine months. The control group consisted of 1,000 students, also in grades three through seven, in classes where normal instruction was supplemented with programmed instruction, films, film strips, and other media. The cost per student for those materials was approximately equal to the cost per student for CAI in the experimental group. All the students attended schools eligible for Title I funds so were, in general, academically disadvantaged.

Pretests and posttests were used which yielded scores on arithmetic computation, concepts, applications and a composite score. A summary of the results is shown below.

Gains in Grade Levels

	CAI	Non-CAI
Computation	.7	.8
Concepts	.8	.9
Applications	.9	.6
Composite	.8	.9

Thus the CAI students gained more than the non-CAI students in applications while the reverse was true in computation, concepts and composite.

Street also compared gains by grade level and sex. There were no significant differences by grade level. However, boys in the CAI group gained an average of .6 grade levels while the girls gained an average of 1.1. In the non-CAI group, the boys gained an average of .9 and the girls .8. Thus, in this

study, contrary to the results found at TIES, the girls did better with CAI than the boys.

Abramson and Weiner (1971) compared the results of CAI arithmetic drill and practice with normal classroom instruction for students in grades two through six in New York City, for two years. During the first year, 1968-69, the results strongly favored the CAI. However, during the second year, 1969-70, the results favored neither group, even though many of the same students were involved. He concluded that this may have been because CAI was innovative to the students the first year, but the newness had worn off by the second year.

Arnold (1970) and Scrivens (1970) reported the results of CAI drill and practice in Waterford, Michigan. During 1968-69 CAI drill and practice was used in grades three through six. In 1969-70 it was used in grades two through six. In both years gains on standardized arithmetic achievement tests were compared between the CAI students and students receiving traditional instruction. During 1968-69, the CAI students in grades three and four gained more than the non-CAI students, the fifth grade non-CAI students gained more than the CAI students, and the gains were the same for the sixth graders. During 1969-70, however, the gains at all grade levels, two through six, were greater for the CAI students. The differences in gains between the groups for 1969-70 were .3 grade levels for grade two, .5 for grade three, .4 for grade four, and .5 for grades five and six.

Crawford and Gipson both studies the effect of CAI drill and practice in

remedial 7th grade arithmetic. Crawford (1970) found that over an eight week period a CAI group gained more than a group receiving traditional instruction.

Gipson (1971) measured gains in arithmetic ability of 7th grade remedial students with both a standardized test (WRAT) and a test specially designed to measure the objectives of CAI drill and practice. In that study, the gains as measured by the special test were significant although the gains as measured by the standardized test were not

Cole (1971) studied the effect of CAI drill and practice on computational skill of high school general mathematics students. He found that the students in the CAI group did significantly better than those in a control group.

Language

Wilson and Fitzgibbon (1970) report some findings regarding student achievement in fourth and fifth grade English, based on a pilot study conducted as part of the Title III Project INDICOM in the Waterford Township Schools of Pontiac, Michigan. The CAI program included instruction in English grammar, mechanics and usage. Each grade level program consisted of 180 core lessons, including a 15-minute drill period and supplementary materials for individualization and enrichment.

Three groups were chosen from intact classrooms of fourth and fifth grades. An experimental group of 68 students received computer assisted instruction in both English and mathematics. One control group (42 students) received CAI drill and practice in math, but not in English. Another control group had no

involvement with CAI. Equal blocks of time were devoted to language arts instruction for each group.

The Stanford Achievement Test was administered to all groups prior to the CAI study, and also as a posttest to determine achievement gains. After four months of treatment, the experimental group receiving CAI in English was found to have a mean grade equivalency gain of seven months (or three months more than expected). The two control groups achieved a gain of three months, or one month less than was anticipated.

In the area of foreign language applications of computer assisted instruction, Morrison and Adams (1968) reported some preliminary findings from a pilot study of a CAI laboratory in German at the State University of New York, Stony Brook. One section of students taking introductory German met with an instructor for three class periods per week, but also received laboratory drill and practice through the use of computer assisted instruction. A second section of introductory German, taught by the same instructor, used a conventional language laboratory. The authors reported that the CAI students acquired speaking and listening skills about as well as students in the conventional language laboratory section, and performed as well or better in reading and writing.

In a follow-up study of the Stony Brook German CAI laboratory, Adams (1969) found that students who were taught reading and writing skills by CAI received much higher scores in these areas on the Modern Language Association Foreign Language Cooperative Tests than did students in the non-CAI group.

Mixed Modes

The research described above involves CAI programs that primarily fit one of the four basic CAI modes. Many CAI programs in use combine two or more modes. Following are the results of research on the effectiveness of such programs.

Diamond (1969) reported on the effectiveness of two CAI programs in Philadelphia. They were in the areas of reading and Biology and both combined tutorial CAI with CAI drill and practice. Both programs were used for grades eight, nine, and ten in one junior high and two high schools. To measure the effectiveness of the programs, some students received CAI instruction while others received traditional instruction. The Gates-MacGinitie reading test was used to measure comparative gains in reading. The results showed that in the junior high and one of the high schools the CAI students gained significantly more than the traditionally instructed students in accuracy, vocabulary, and comprehension. In the other high school the gains were about the same.

Both the Nelson Biology test and a specially constructed test were used to compare gains in Biology. The Nelson Biology test showed no advantage for either the CAI or the traditionally instructed group. The specially constructed test showed higher gains for the CAI group than the comparison group. That may not have been a true indication of differences, however, since the CAI students had responded to some of the test items while going through the CAI materials.

Cartwright and Cartwright (1972) reported on the effectiveness of CAI material at Pennsylvania State University that combined tutorial and simulation modes. The CAI programs were used to teach elementary education students about remedial education. Achievement of a CAI group was compared with the achievement of students who received traditional instruction. The average CAI student achieved 24% more than the average traditional student. In addition, the CAI students spent 33% less time learning.

Lagowski, et al (1971) used a combination of three CAI modes--tutorial, simulation, and drill and practice--to supplement normal instruction in chemistry. The students who received CAI as a supplement to traditional instruction achieved significantly more than students who received traditional instruction only.

Observations and Conclusions

When this study was begun it was anticipated that there would be a wealth of research on the effectiveness of CAI. That is not the case. Although there have been some excellent studies of the effectiveness of CAI most CAI programs, many of which are supported through grants from various agencies, have never been evaluated for effectiveness--at least the results have not been publicly reported.

However, based on the research that has been reported, the following conclusions can be drawn:

1. In general, CAI has proven to be an effective instructional tool as measured by the resulting student achievement. It appears to be more

effective in the tutorial and drill and practice modes than in the problem solving and simulation modes.

2. When students are permitted to proceed at their own rate, they will generally learn more rapidly through CAI than through traditional instructional methods.

3. Retention of material learned does not appear to be as high for CAI as for traditional instruction.

4. As a supplement to normal classroom instruction CAI is as effective as other means of individualized supplemental instruction.

5. CAI, especially in the tutorial and drill and practice modes, is relatively more effective for low ability students than for middle and high ability students.

6. Except for times when equipment malfunctions, both students and teachers are highly enthusiastic toward CAI as a means of instruction.

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